

## Potential Internet2 Applications

The document below is a draft developed by Greg Marks, Special Assistant for the K-12 Outreach, Merit Network.

Here are eleven descriptions of potential Internet2 applications. Each description begins with the short phrase we used to characterize that application in our initial announcement. Other applications can and will be added, but this is our starting point.

An appendix is included which covers video, with an overview of the more common options and variations.

These are written primarily with a K-12 school administrator or teacher in mind, and contain only enough technical information or terminology to alert them to factors of relevance to the application. Future revisions will look at how to make them more suitable for use by libraries, community colleges, other higher education institutions, etc.

At this stage of development, all the scenarios are based on plausible uses of Internet2, but it may be the case today that all the pieces are not in place. One of the exciting challenges for early K-12 users of Internet2 is determining what the first real applications will be.

## Potential Internet2 Applications

*1 From: Language students talking "face-to-face" with students in a foreign country.*

### **Language Students Talk with Students in a Foreign Country**

#### **Example Scenario**

You have a teacher who wants students in a French language class in your school to be able to use video teleconferencing to talk face to face with similar age-level students in a classroom in France. Internet2 opens up that possibility.

The teachers want to begin these interactions by having the students build a base of familiarity with each other. So, two "familiarization" sessions are planned. The students in both countries produce a short video or photo tour of their hometown, probably in the form of a walking tour. The tour will feature frequent stops, each stop a vignette that illustrates everyday life and culture. In the first session, the French video is shown. A conversation in French follows, and the teachers on both sides ensure that the students in each class ask questions and make observations. At the second session, the American students do the video and photo tour of their town, and the conversation is in English.

In subsequent classes, small groups of students (two or three per group) from each class use video teleconferencing running on the schools' desktop computers to have conversations with each other. They are scheduled to have half the conversation in French, half in English. They start by talking further about what it is like to live in their town and then progress on to other topics, such as popular music, movies, clothing, school, food, transportation, the prices of common items, and sports. Students write stories for each other and discuss what is being said and how it is said. They read and discuss short stories and other literature.

#### **Benefits**

Students will be motivated by interaction with someone of their own age, yet living in a different country and culture. They will see how others are struggling or succeeding with English just as they are with French, and they will learn about the quality of the French students' language skills, general educational attainment, and something of their daily lives.

Hearing a variety of native-language speakers is enormously valuable for gaining an "ear" for the language. Hearing their spoken language helps focus on the essential parts of vocabulary and grammar for conversation. Discussion of written works helps students identify and understand differences in meaning, including how mistakes in expression can be both confusing and funny.

#### **Information Links**

To be done

## Potential Internet2 Applications

**2 From: Music students coached by virtuoso teachers from a distant site.**

### **Music Student Benefits from Distant Teacher**

#### **Example Scenario**

You have a student in jazz band in your school. You believe the student would benefit from contact with real jazz musicians. You learn that one of the schools in New York City has arranged a “master class” in which local jazz performers spend an hour with a class that is in multiple distant locations, via a video teleconference on Internet2. You schedule your student for one of the master classes. After several sessions the student and your local music teacher both tell you that it has been a great learning experience, and you can see the student is really motivated by what was learned.

#### **Benefits**

The remote musician will see and hear your student’s technique and interpretive skills. The jazz player will comment and advise, and will also demonstrate with their own instrument the kind of technique and style they’ve been talking about.

Your student and the remote jazz musician will communicate and play *for* each other in a way that is just as exciting and motivating for a student as contacting a scientist is for another student in a science class. However, they cannot play *in unison* because even the slight time delays between these distant sites are too long. But, they can accomplish most of what would be gained by an in-person visit, without the expense of travel and with a much greater likelihood of having contact with top-quality musicians who have demonstrated they are also effective with students.

#### **Information Links**

<http://real.ny1.com:8080/ramgen/real/PB00725hi.rm>

## Potential Internet2 Applications

*3 From: Virtual field trips to museums or remote sites made more meaningful because of greater detail, responsiveness, and "virtual reality" exploration of a room or space.*

### Virtual Field Trip

#### Example Scenario

The Royal British Columbia Museum in Victoria, British Columbia has begun offering virtual tours of its exhibit of early Northwest Coast Native artifacts and culture.

Tours may be assembled from:

- live discussion and interpretive walk-around with a museum staff member;
- use of a student-controlled camera inside a replica of the Bighouse native lodge;
- viewing of historic photos and film clips;
- and observation of an Indian carver using traditional methods to craft a totem pole.

Some of the tour is experienced by the class as a group and some by individual students as they explore on their own.

#### Benefits

Students can tour those museums, zoos, nature centers, etc. the distances to which make them too expensive for traditional field trips or even for today's video-based virtual tours. (Video field trips today typically use high-capacity telephone circuits to reach the remote site and so are subject to substantial long-distance charges.)

Remotely controlled cameras and exhibits can be operated by students, giving them more control over what they learn and allowing them to follow their curiosity and inquisitiveness.

Museums and zoos can place high-quality video clips and photos on-line, with quick response to student selection and high-quality display, greatly extending each student's ability to explore on their own, much as they would if they were visiting in person.

#### Information Links

< <http://rbcm1.rbcm.gov.bc.ca/> >

## Potential Internet2 Applications

*4 From: Interaction between a student teacher and an established classroom teacher, or involving college faculty.*

### **Helping Schools, Ed Schools, Student Teachers Interact**

#### **Example Scenario**

Your school has a long history of working with student teachers from a nearby university's education school. Travelling between the university and your school consumes a lot of time, but is considered a regrettable necessity. You also feel that you need more discussion with the faculty at the education school, because you're trying to change what is taught and how it is taught, and you'd like to have the student teachers better prepared for the new direction in which your school is heading. This calls for more communication, yet everyone is concerned about travel time. The telephone is just not good enough. Video conferencing via Internet2 offers an important new option.

Immediately you learn that the student teachers are very happy because they can interact over the teleconferencing system. They can conference from your school to talk with faculty mentors back at the university or from the university to whomever is appropriate at your school to discuss their student teaching. They feel this has made for a much better student teaching experience.

Your school's media department establishes a connection to the video teleconferencing system from the classroom video cameras. This allows faculty and students at the university to observe what's happening in the classroom, including remote observation of how a student teacher is doing.

These successes open yet more opportunities for collaboration between the school and faculty at the university.

#### **Benefits**

Video teleconferencing permits a variety of interactions among teachers, student teachers and university faculty that are nearly as good as in-person contacts, and yet do not involve the time and expense of traveling to be in the same place. This changes the nature of the interaction among these people enormously and helps everyone work together much more effectively.

#### **Information Links**

To be done

## Potential Internet2 Applications

*5 From: Science students who utilize rare or expensive remote instruments such as electron microscopes, telescopes, or other devices that allow them to explore worlds outside their classroom.*

### Remote Use of an Electron Microscope

#### Example Scenario

Several students are preparing Science Fair projects that involve descriptions of segments of human DNA. They are aware of the large database produced by the Human Genome Project and are planning to use the portions of that data relevant to each of their topics. But they are especially surprised and excited to learn that Internet2 gives them access to scanning electron microscopes at the University of Michigan College of Engineering Electron Microbeam Analysis Laboratory (EMAL).

After a video teleconference with a genetics specialist at the University's Medical Center and a lab technician at EMAL who is an expert on microscope use, they prepare appropriate blood samples and ship them to the University's lab site.

They schedule a time at the electron microscope that is best suited to their plans. Using Internet2, they work with the microscope from computers at their school. They view the image generated by the microscope on their computer screen and use the keyboard and mouse to operate the instrument.

The students quickly learn to operate the equipment and are amazed at the level of detail they can explore. But just as quickly, they realize that identifying which part of the DNA is on-screen is quite difficult. They contact the genetics expert and reschedule their time on the microscope, so the expert can work in parallel with them to help them understand what they are seeing, connecting their computers in parallel, using a shared screen and a voice channel to communicate with each other.

The expert guides the students to the structural clues in the DNA. After a few minutes of checking the students' understanding, the expert signs off. The students quickly find the relevant portions of the DNA for each of their experiments and are ready to combine images they've captured into their science projects. The combination of the human genome data and the images allows each student to give a very professional presentation for the Science Fair.

#### Benefits

The ability to use a serious, real scientific instrument will provide the students with an incredible sense of what science involves and what is possible. The difficulties of using the instrument and of identifying structural elements of DNA present authentic learning experiences. Students will explore topics in ways that are unimaginable for individual schools.

In this scenario we also see benefits from Internet2 video teleconferencing, facilitating communication about the use of the microscopes without requiring any travel. Similarly the shared access via computer to the instrument controls and display, with voice communication, greatly facilitates the quick resolution of problems, ensuring the students have a challenging but positive experience.

#### Information Links

< <http://emalwww.engin.umich.edu/emal/fset.html>>

< <http://www.nbr.wisc.edu/outreach/>>

## Potential Internet2 Applications

*6 From: High quality video interaction with remote experts at the Smithsonian or astronauts working on the international space station.*

### **High Definition Video from the International Space Station**

#### **Example Scenario**

NASA has produced many events and learning materials for students that are highly informative and motivating. Soon the international space station will be broadcasting high definition television (HDTV) images from both inside and outside the space station. These will be accompanied by opportunities for students to ask questions, through email or via video uplinks.

#### **Benefits**

This HDTV service will produce images that are exciting and motivating to students. Indeed, they will be able to gain much better detail and sense of “being there” on school computers than will be possible with TVs in most homes. It will seem almost as though the students are in the space station with the astronauts, seeing things just as they see them.

Communications with the astronauts and with other experts on the ground, means that students can ask questions, becoming part of a large group discussion that is spread over an enormous geographic area. This is a kind of group experience that is likely to become increasingly common in the future, as well as being informative and motivating simply because of the impact of the views from space.

Note: there are multiple formats for the delivery of HDTV. The least demanding of these, 480i, will require on the order of 8 Mbps of bandwidth. HDTV adapters are available as plug-in cards for desktop computers and the larger monitors are capable of displaying the 480i image. Thus there is potential, at least in principle, for this in the classroom.

#### **Information Links**

< <http://www.spaceviews.com/2000/06/02b.html>>  
< <http://www.dreamtime.com/hdtv.html>>  
< <http://www.ssl.umd.edu/space/data.html>>

## Potential Internet2 Applications

*7 From: Using multicast video technology to deliver lectures, demonstrations, and performances to large audiences distributed across the country that would normally require broadcast television or satellite video delivery.*

### **Live from the Kennedy Center for the Performing Arts**

#### **Example Scenario**

The Kennedy Center for the Performing Arts in Washington D.C. has been planning a series of performances by outstanding modern dance companies. Dance instructors in schools across the country are very interested in having their students see these dance performances. They would prefer to see them “live” while they are happening, rather than later after videotape is edited and distributed. They believe the excitement and tension of the live event is important to the experience. They want their students to be able to read and comment on the reviews of professional critics, and be able to discuss their own reactions with students from other schools. All these things require seeing the performance as it happens. Indeed the teachers desire video that is of higher quality than videotape, so their students can see subtle elements of movement, personal expression, and the character of the staging and lighting.

#### **Benefits**

Transponder time for classic satellite delivery is very expensive, and the bandwidth of the commodity internet is insufficient for live delivery. Even for Internet2, the bandwidth demands must be handled by appropriate use of the technology, because as many as 5,000 schools across the nation and abroad are planning to watch the performance. If each one requires a separate stream of video, the aggregate amount of bandwidth would saturate even Internet2’s backbone. The answer is to use a technology known as “multicast” within Internet2, that delivers the video via one stream on the backbone rather than 5,000.

Internet2 with multicasting is a way to “narrowcast” video to groups that are too small to be economically served by traditional broadcast media. If desired, the video quality can be higher than for traditional media as well.

The geographical region that can be covered in such multicasts extends beyond the boundaries of the U.S. Many other nations have national networking efforts that are comparable to Internet2 and also offer multicast. Multicast sessions could originate in other countries for viewing a performance, event, or presentation. Video originating anywhere in the U.S. can be immediately seen in many other parts of the world.

#### **Information Links**

< <http://kennedy-center.org/> >

## Potential Internet2 Applications

*8 From: The University of Michigan's Visible Human Project that makes it possible to "fly" through and view the detailed digital anatomical database of the human body that is being created by the National Library of Medicine.*

### Virtual Anatomy

#### Example Scenario

A health sciences class is studying human anatomy. To give the student the most vivid possible exploration of the subject, the teacher is using the display of the body that is offered through a multi-institution Visible Human effort that includes the University of Michigan Medical School's work on advanced visualization over Internet2. Students are able to sit at school computers and navigate using a keyboard and mouse, examining any part of the human body.

They can examine layers of muscle, study the structure of major organs, look at bone structure, and see how these all relate. The student can look at cross sections of the body from any angle. Each student focuses on a specific part of the body and prepares a report, incorporating animated images that are obtained from their individual work with the Visible Human database.

#### Benefits

Students will experience the amazing complexity of the body, navigating through it at the pace and in the manner that matches their own curiosity and whatever paths they must follow to complete their assignment.

#### Information Links

< <http://vhp.med.umich.edu/>>

< [http://vhp.med.umich.edu/VisHuman\\_LR.mov](http://vhp.med.umich.edu/VisHuman_LR.mov)>

## Potential Internet2 Applications

*9 From: Access to extensive photographic and video archives maintained by NASA and many other organizations.*

### Truman Presidential Library

#### Example Scenario

Students are working on multimedia “papers” the United States right after World War II. They learn that the Truman Presidential Museum & Library has a wonderful on-line collection of materials about that period, including video clips of President Truman as well as other clips covering many of the major events of the time. A large collection of digitized photographs is included as well as many presidential and other governmental letters and documents, audio recordings, and other materials that portray the history of the period in which Truman served as President.

Each student has chosen a different topic and has a number of other sources of on-line material beyond the Truman Library. Yet, each finds the Library’s collection very rich, and this leads them to explore in great depth. The students explore well beyond the basic parameters of simply completing the assignment, enriching and reinforcing the curricular objectives.

#### Benefits

Looking at source materials describing what happened and covering the steps to decisions is an invaluable lesson for students. Searching through these materials on Internet2 is quicker and less foreboding than actually going to a major archive such as the Truman Library, as well as obviously being something a student can manage without travel.

#### Information Links

< <http://www.trumanlibrary.org/index.html> >

## Potential Internet2 Applications

*10 From: Access to extensive archives of environmental, social, and other science data.*

### Individual's 2000 Census Data

#### Example Scenario

You have a social science teacher who wants students to learn more about the social structure of your community and wants them to use data so they understand the science involved.

In the past they have used the tabulated U.S. Census data, but students find this dry and daunting. The teacher learns that in January of 2002 the U.S. Census Bureau will release a very large data collection known as the Public Use Microdata Sample (PUMS). These data are samples of the individual data, for either 1% or 5% samples of households in the entire U.S. All individual identification is removed to ensure the confidentiality of the individual responses. Each response can be identified according to a local geographical area that is a subset of a county, a full county, or multiple counties, structured to represent about 100,000 people. Thus for a county of 100,000 people, there are either 1,000 (1%) or 5,000 (5%) people in the data for that county. Within large cities, there will be multiple such data areas for the whole city.

A student may look at the data for just their own geographic area, or they may compare it with other geographic areas of their choice, or look at entire states, or look at regions or the whole U.S. Similar PUMS data collections are available for 1990 and 1980, so it is also possible to look at change over time.

The use of such data has historically required considerable computing and very skilled people.

With Internet2 and suitable PC software it is possible for students to do readily understood tabulations from these data, in effect doing real social science research, learning how to formulate good questions and find data to answer those questions.

Your social science teacher decides to use these data and discovers that the students quickly catch on to framing questions, looking at tabulations and percentages, and describing the demographics of their community and how it compares to others. The students get into "did you know?" contests with each other, comparing their ideas about the community with actual data. The teacher sees this as a great success.

#### Benefits

Many kinds of scientific data are available over the internet, but the data collections are so large that only with Internet2 is access quick enough to make them viable for student projects. Working directly with data is very effective as a "constructivist" method for student learning about the subject covered by the data. Use of such data is also important because it helps students understand the relevance of data to major public and business questions that are a part of decisions made every day by leaders in this country. As future citizens they should understand how to access and use data themselves, as well as have a sense of its limitations.

#### Information Links

<<http://www.census.gov/dmd/www/schindex.htm>>

<<http://www.ipums.umn.edu/usa/intro.html>>

< <http://www.pdq.com/>>

## Potential Internet2 Applications

*11 From: Access to high performance computational clusters and other forms of "Grid" computing where computers, data, and other resources from many separate locations are coordinated to work on problems that are too large for any single site or organization to take on alone.*

### Showing Students What's Happening

#### Example Scenario

There are many topics in science, math, and other areas where the teacher wishes there were some form of animation or virtual reality available to illustrate the principles, models, behaviors or sequences of events that would show the students what is happening in an "I see what's going on" experience. Simple forms of these are now available on individual PCs (for example the series that started with SimCity). However advanced applications like these require a combination of high performance computing to do the animation or visualization and high-performance networks to link the data to the computers.

With Internet2, these computational resources will reside outside the school, delivered seamlessly to the school over the high-performance network.

One example of this could involve students assessing one or more aspects of their local environment, such as looking at land use and water quality. Data collected by students at multiple local sites could be combined with state and federal data in a Geographic Information System (GIS). This would allow students to examine the relationship among various levels of vegetation; industrial, retail and residential use; water quality; and other environmental factors, all in the form of integrated maps displayed on their computer screens.

#### Benefits

Students will more readily grasp complex objects, concepts, environments, and other phenomena through graphic displays that might be manipulated interactively. Interactive manipulation/exploration will provide the opportunity for more in-depth understanding.

#### Information Links

<http://spatialodyssey.ursus.maine.edu/gisweb/spatdb/gislis95/gi95006.html>

<http://www.riveredgenc.com/html/landuse.html>

[http://www.dnr.state.mi.us/spatialdatalibrary/Site\\_Map.htm](http://www.dnr.state.mi.us/spatialdatalibrary/Site_Map.htm)

Other sites with information on computation/network grids:

<http://www.evl.uic.edu/tile/>

<http://www.eot.org/edgrid/index.shtml>

<http://www.gridforum.org/>

<http://www.ncsa.uiuc.edu/alliance/access-dc/>

## Potential Internet2 Applications

### Appendix 1 Video

This section provides information about video that is relevant to many of the Internet2 applications described elsewhere.

#### Major variations in the use of video

##### *One-way*

1. The classic use of video is what we watch on home TV sets, whether from broadcasts or videotape. This is one-way in that the transmission comes to the viewer, and there is no means of feedback or communication back to the source.
2. When video is combined with various graphics, text, still photos, and sound elements, often with the video in only a portion of the display screen, perhaps not visible at times, then we have what is commonly called a multimedia presentation.
3. When a multimedia presentation can be controlled by the user, for example, to select the desired path through the material, this is interactive multimedia. Note this is still one-way, because there is no person at the other end to receive any communication.

##### *Two-way or more*

1. An extension of the classic one-way video that is sometimes used is one where some simple means is used for feedback, such as a keypad, email, or phone-in.
2. There are a variety of video applications in which two or more people are at different locations and they wish to have a video-based interaction with each other. The purpose is to allow everyone an equal ability to communicate with everyone else. This is usually termed video conferencing.
3. When there is a primary channel of video, such as a person teaching or making a presentation, and that person has one or more channels of video in which they can see and hear their audience in distant locations, it is called distance education or distance learning.

#### Video quality: basic protocols or products, bandwidth requirements

All of the following are ways of providing digital video. Each has a process for encoding to produce the digital video and decoding to put it in a form suitable for display; the specific implementation is referred to as the type of "codec" used (*code/decode*). There is a mixture of protocols (standard rules for how something is done) and products here, which will be explained in the course of the discussion.

In each instance, the perceived quality of the video depends on the video production. Poor lighting may lead to a low-contrast, washed-out image. Complex backgrounds, strong variations in colors, and rapid movement may lead to visual artifacts known as dot crawl, blocking, or pixelization. These problems become greatly exaggerated when the video is being delivered at a low bandwidth.

## Potential Internet2 Applications

In many instances the quality of the audio is much more important than the quality of the video. If the audio is not of at least reasonable quality, users will quickly leave. Fortunately, good audio is possible at relatively low bandwidths compared to the video.

### *QuickTime, RealPlayer, Windows Media*

These are the three dominant products for delivering (the server) and receiving (the player) video over today's internet. They may also be used for audio-only, such as with RealAudio. RealPlayer was the first to be able to provide passable video over dial-in connections and the others now offer roughly similar capabilities. Each is capable of much higher quality as the bandwidth increases.

Each of these products provides multiple codecs, some of which are optimized for low bandwidth network connections (e.g. dial-in), others for faster connections, and yet others for purposes of compatibility with common standards. Each of these has a stand-alone player or may instead be incorporated in a web page, and are capable of at least a modest level of multimedia or interactive multimedia presentation.

At speeds of 300k bps (bits per second) and above, each of these products provides quality that the untrained observer might say starts to compare to a VHS tape. The most serious problem with such speeds over the commodity internet is having that much bandwidth on a sustained basis, so that the video stream isn't constantly pausing as bottlenecks in the network occur.

### *MPEG-1*

The Moving Picture Experts Group (MPEG) has developed several standards for encoding and decoding video. MPEG-1 is intended as a video stream that can be played from a CD, with a bandwidth of about 1.5 Mbps required. It is of approximately the same video quality as VHS videotape.

There are actually a range of bandwidths that are used with MPEG-1, and MPEG-1 codecs are available for RealPlayer and Windows Media, which means that some commodity internet content is today found in MPEG-1 format. It usually requires a complete download of the video file, however, rather than it being possible to play the video right from the start after connecting, as a stream.

### *MPEG-2*

MPEG-2 was developed to provide broadcast TV quality or better, and is widely used today on DVDs and satellite TV services such as DirectTV. It typically requires about 6 Mbps of bandwidth, although it can go lower with some loss of quality. Variations in use of this protocol can drive the bandwidth higher or lower, but under any circumstances this form of video is viable only over a high capacity Internet2 network.

### *HDTV*

HDTV is capable of a much higher quality video display than today's normal TV broadcasts or DVDs. However, it requires upwards of 8 Mbps and often much more than that to deliver, which means that HDTV is viable for only the best-equipped Internet2 sites.

### *H.261 and H.263 (included in H.320 and H.323 protocols)*

## Potential Internet2 Applications

H.323 is a suite of protocols for video teleconferencing over the Internet. It is an adaptation of the H.320 protocol suite that has been in use for years for teleconferencing over ISDN or other dedicated or dialup lines. One of the major protocols supported within H.323 is H.26x video, where H.261 is a required level of support for video and H.263 is a more advanced codec that is optional. The codecs to support these protocols can operate as low as 128kbps, or as high as 2.0 Mbps.

H.261 can provide images of 128x96 pixels in size, 177x144, or 352x288 (which is similar in quality to VHS videotape). H.263 can provide each of those three, plus 702x576 and 1408x1145 pixels. The change in number of pixels displayed is directly related to the bandwidth that will be required.

The crucial difference in these protocols compared to all the other video options listed earlier is that these codecs are designed to operate very rapidly, so that the encoding and decoding are fast enough for people to interact. That is, for people to talk to each other, the delays must be well under a second. The other video options typically involve delays of many seconds, if not minutes, which makes conversation impossible.

One of the ways in which this speed is gained is through use of specialized hardware to perform the codec functions. There are also programs that don't rely on specialized hardware, simply taking advantage of however much speed the desktop computer has; two common examples of H.323 compatible software are Microsoft NetMeeting and CuSeeMe Pro.

### **Video quality: QoS (Quality of Service) or Class of Service**

Good video requires a predictable level of bandwidth. If a network is lightly loaded, so there is more than enough spare capacity for the video, everything is fine. However, a network that is unloaded at one point may become highly loaded at another. That will cause the video to stop or break up, and depending on the application, very much of that may make the video unusable.

A solution to this is QoS or a simpler alternative known as Class of Service. Work is proceeding to implement this within Internet2. In both cases the idea is to give priority to the video stream or guarantee it has a certain amount of bandwidth. Unfortunately, this is easier to talk about than to implement, and as a result in most cases today reliance is placed on having plenty of spare bandwidth. Merit is working on solutions, as are others using Internet2, and they will be announced when available.

### **Video quality: compression**

All the codecs described above do some level of compression, which involves finding identical or similar parts of the video image and storing information about how many duplicates there are rather than all of the individual pieces. The resulting compressed form may be one-half or even one-tenth of the original. At higher levels of compression, some visible loss of image quality results. If the image has lots of detail or motion, the chance of visible problems is much greater. It also takes more compute power to deal with higher levels of compression. Higher levels of compression are used more on the commodity internet in order to reduce bandwidth requirements, but the result may be more visible compression artifacts or problems in the video. With Internet2, less compression is often possible, with resulting higher quality images.

### **Video quality: latency, jitter and buffering**

## Potential Internet2 Applications

The first several one-way video products and services that are described above all entail allowing the video to run for a substantial fraction of a minute, in order to be enough ahead of any problems in the commodity internet that the actual video presentation looks smooth. This is the same principle that leads cities to store water in tanks or reservoirs, so that if the source runs dry, they still have water for residents. This is called buffering.

In the case of two-way video, such as video teleconferencing, the time delay imposed by the buffering makes any conversation very awkward. So such buffering is not possible, and this is the path taken by the H.323 protocol devices.

But even for the H.323 devices, another pair of network characteristic are important. One is the delay time from when something is done at one end of the network to when its effect comes back to the originator. This is called latency, and indeed large buffers are one source of too-high latencies. It is crucial to a good conversation that latency be low.

If latency is just barely acceptable, then it needs to always be close to the same amount of delay. If it varies too much, sometimes being very short and sometime noticeably long, it is much harder to have a conversation. This variation in latency is called jitter.

The Internet2 backbone is engineered to have both low latency and low jitter.

### **Video for a large audience: multicast**

If everyone viewing an event on video has their own copy of the video data stream flowing to them over the internet, and there are, for example, 20,000 users then it is evident that almost any backbone could become clogged.

An alternative is available through what is called multicast. Under multicast, the network devices than arrange the flows of data through the internet, called routers, are aware that multiple end-users want to receive a copy of a specific data stream. Thus in the case of the video data stream example above, only one copy of that stream passes over the internet instead of 20,000.

Multicast is implemented in Internet2 so that use of video is much more viable for serving medium to large audiences, avoiding excessive burden on the network. One thing to note, though, is that everyone will be getting the same video at the same time; a multicast is a scheduled event. It does not work for on-demand viewing at whatever time suits the end-user.

### **Information Links**

<http://www.educause.edu/ir/library/pdf/erm0130.pdf>